

# Scaling relations for galaxies of all types with CALIFA and MaNGA surveys.

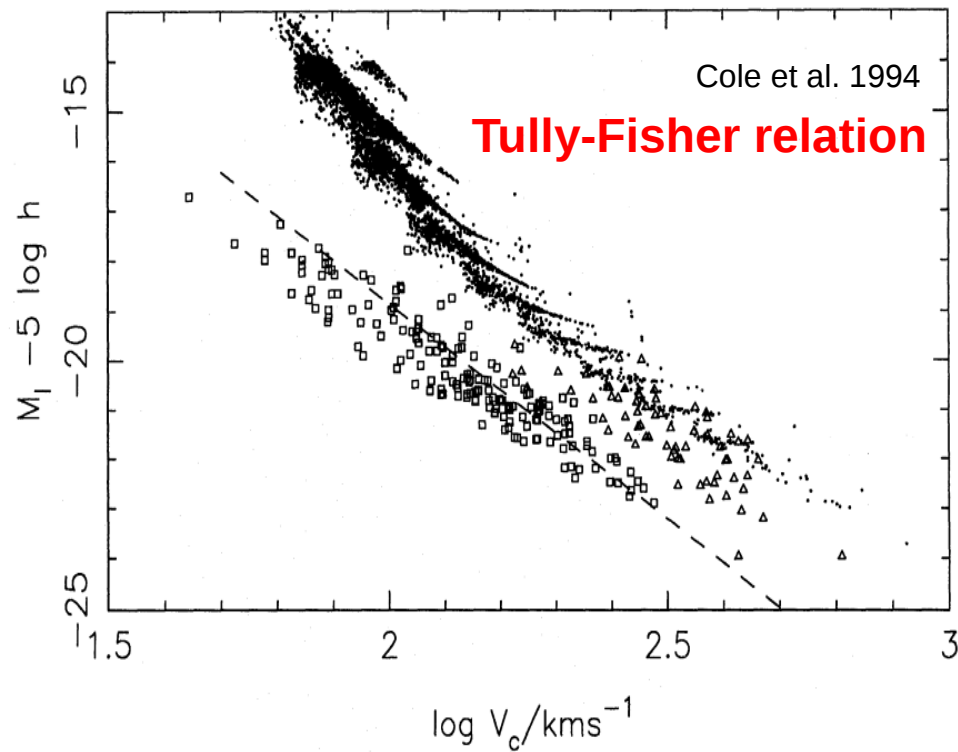
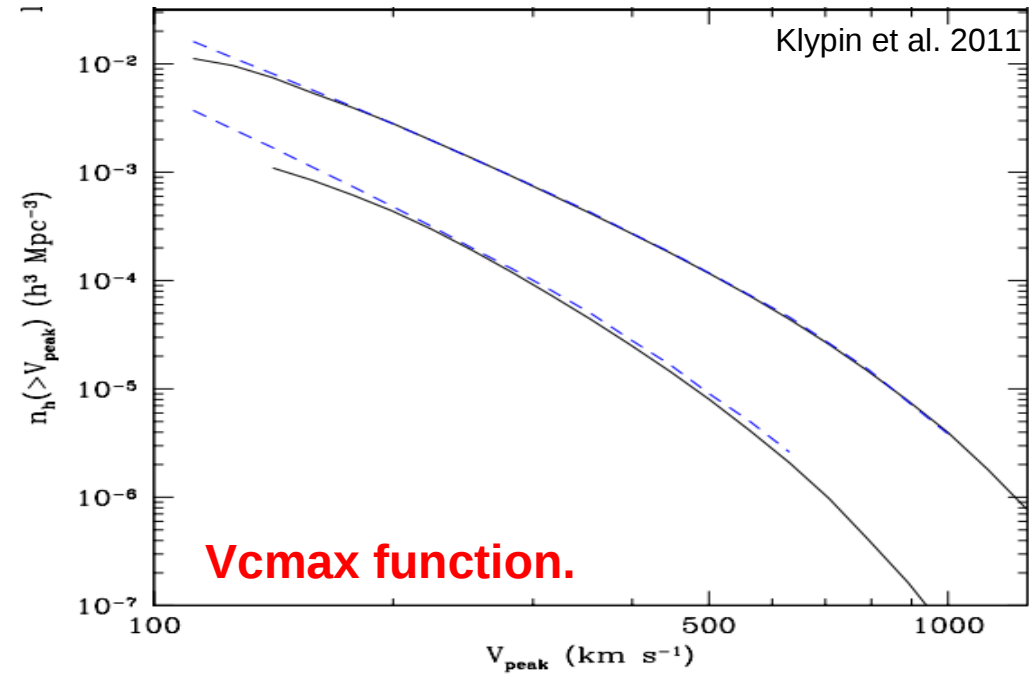
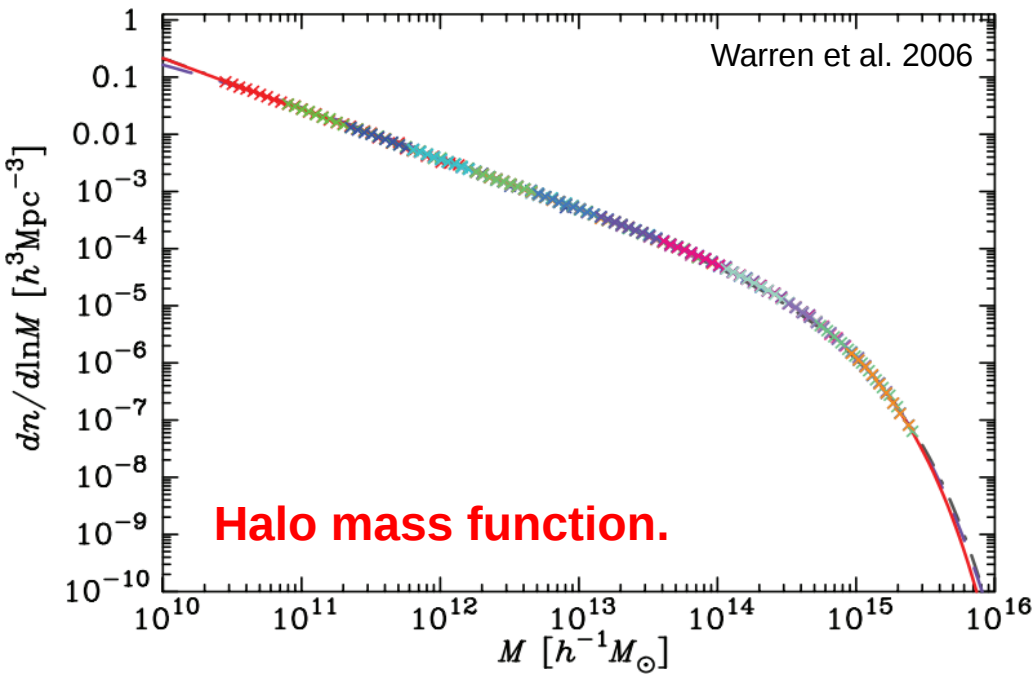
E. Aquino-Ortíz, S. F. Sánchez, O. Valenzuela, M. Cano-Díaz, H. Hernández-Toledo.  
Institute of Astronomy, National Autonomous University of México

MSc. Erik Aquino Ortíz.

INSTITUTO DE ASTRONOMÍA, UNAM.

Cozumel, Q. Roo, 2016

# Motivation: Structure formation in the LCDM.

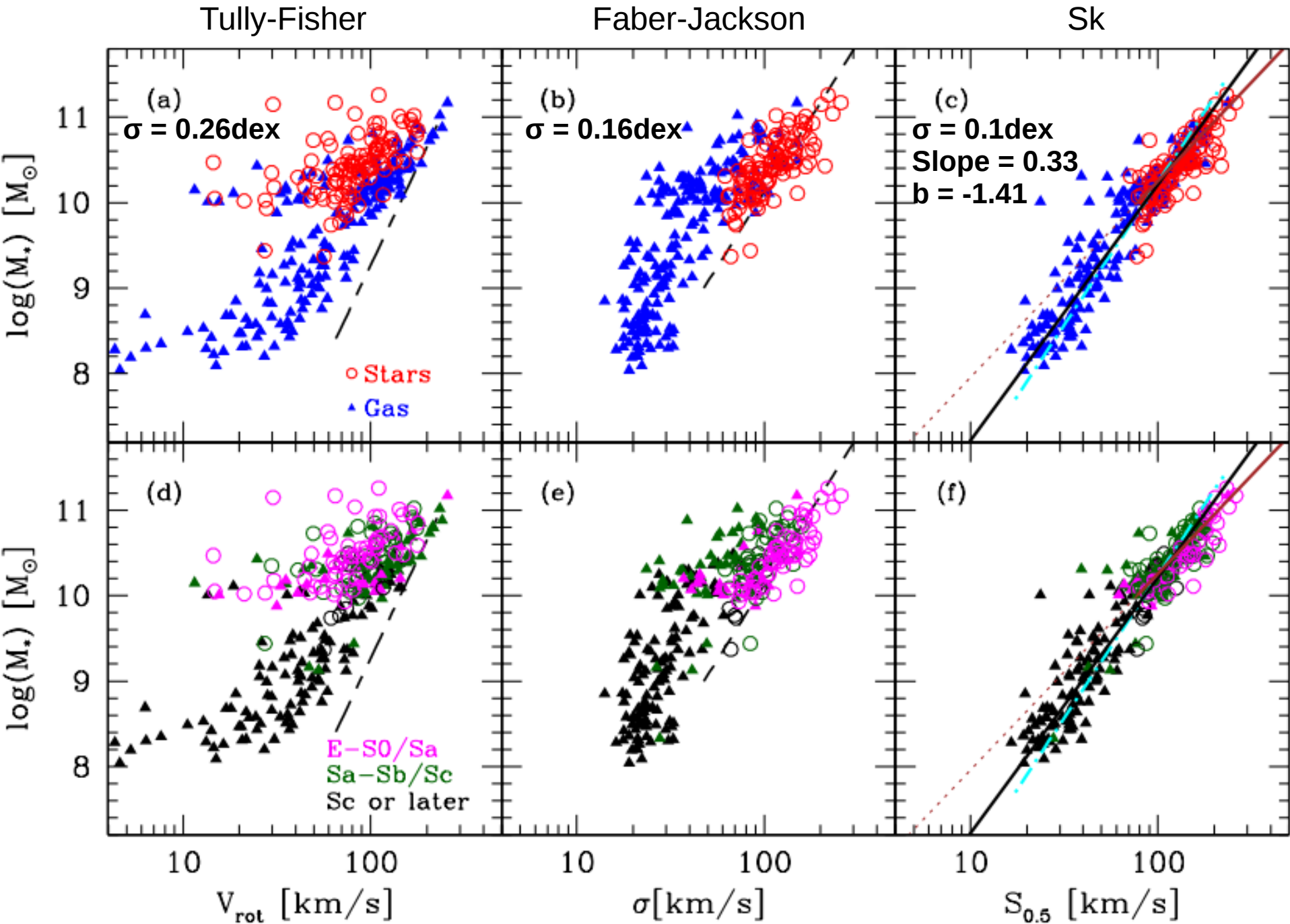


# Motivation: Scaling relations

- Galaxy evolution and environmental effects are likely to modify the shape of Tully-Fisher relation. [Weiner et al. 2006A](#), [Corteu 1997](#).
- Different works have investigating the possibility of bringing galaxies of all types onto the same scaling relation. [Zaritsky et al. \(2008\)](#), [Kassin et al. \(2007\)](#), [Cortese et al. \(2014\)](#)

$$S_K^2 = K V_{rot}^2 + \sigma^2$$

Cortese et al., 2014 - SAMI

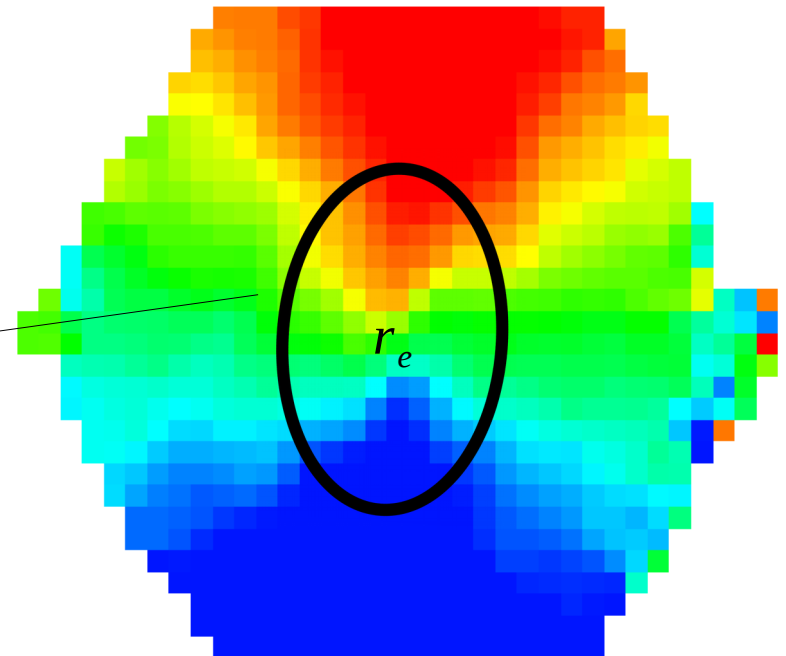
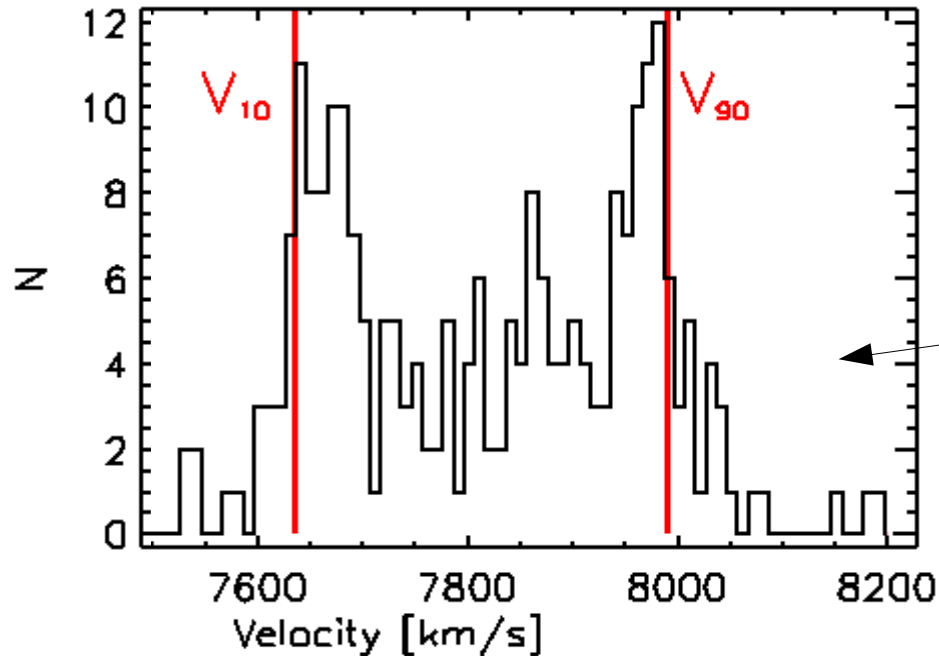


**Methodology:** We follow the same procedure as Cortese et al. (2014)

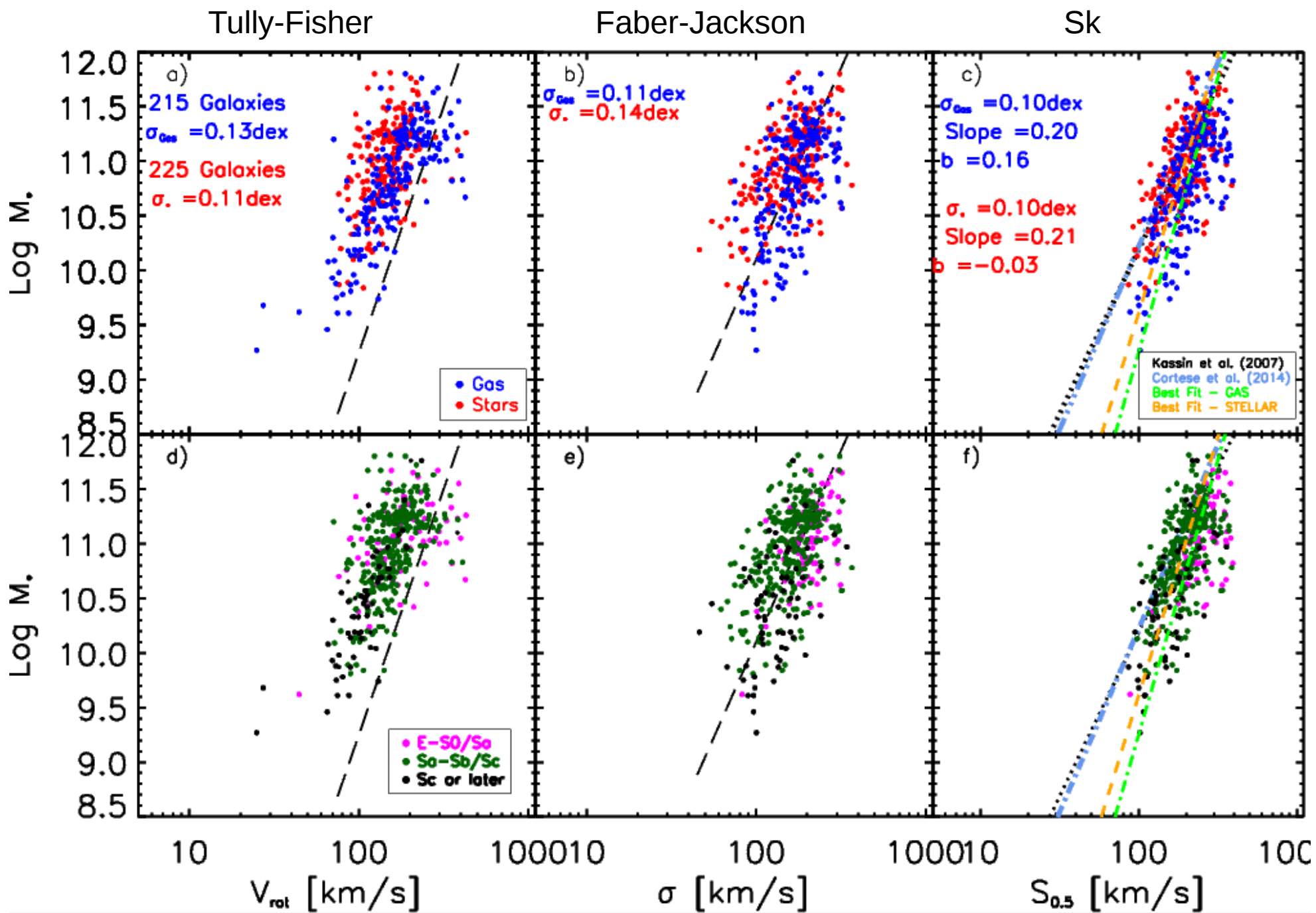
**Line-of-sight velocity and dispersion maps were obtained using the PIPE3D (S. F. Sánchez et al. 2007).**

**Gas and Stellar rotational velocity: *Similar to integrated HI profile***

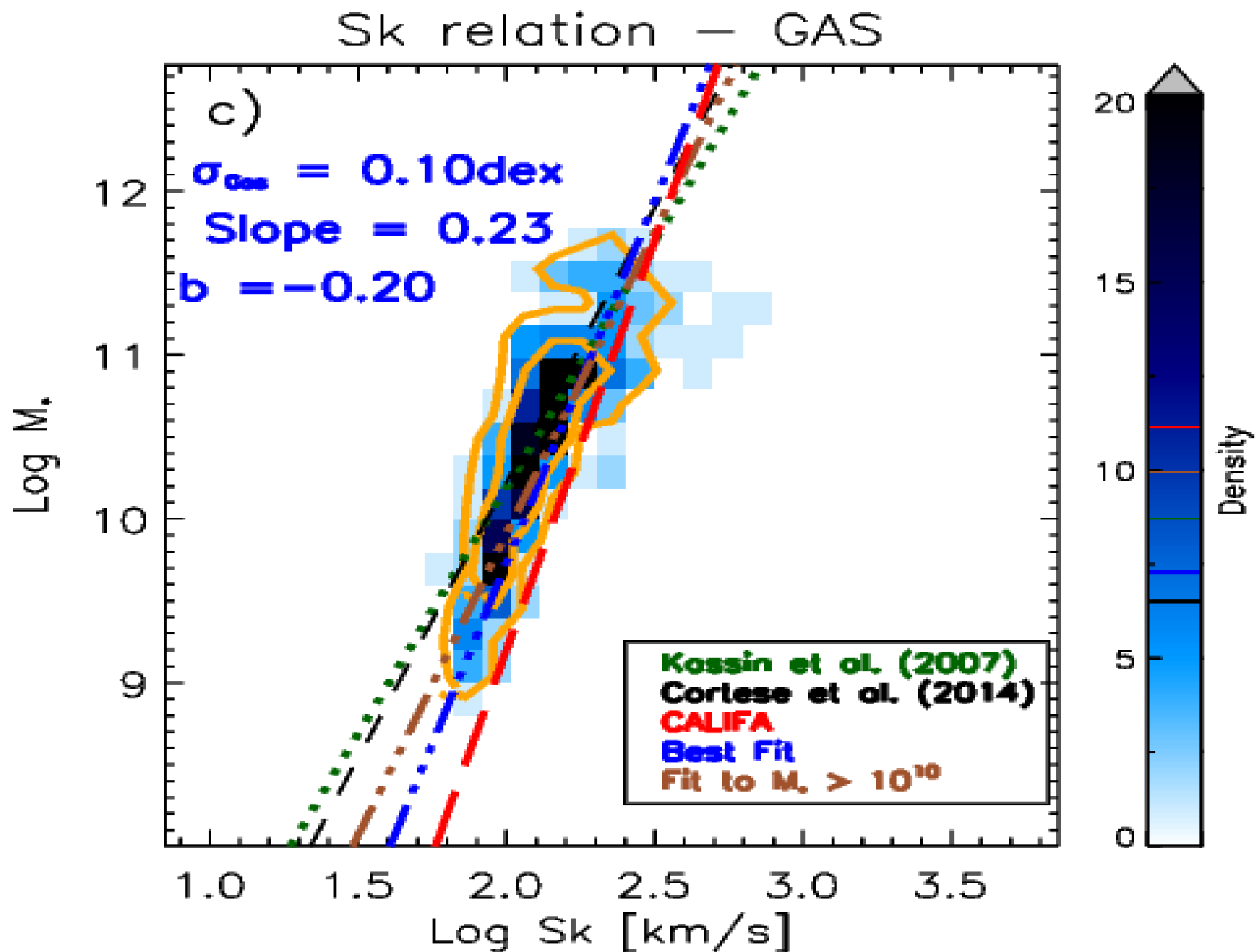
$$V_{rot} = \frac{W}{2(1+z)\sin(i)}$$



# Results: Scaling relations: CALIFA Sample



# Sk Scaling relation: MaNGA Sample **Preliminary results**



# Summary:

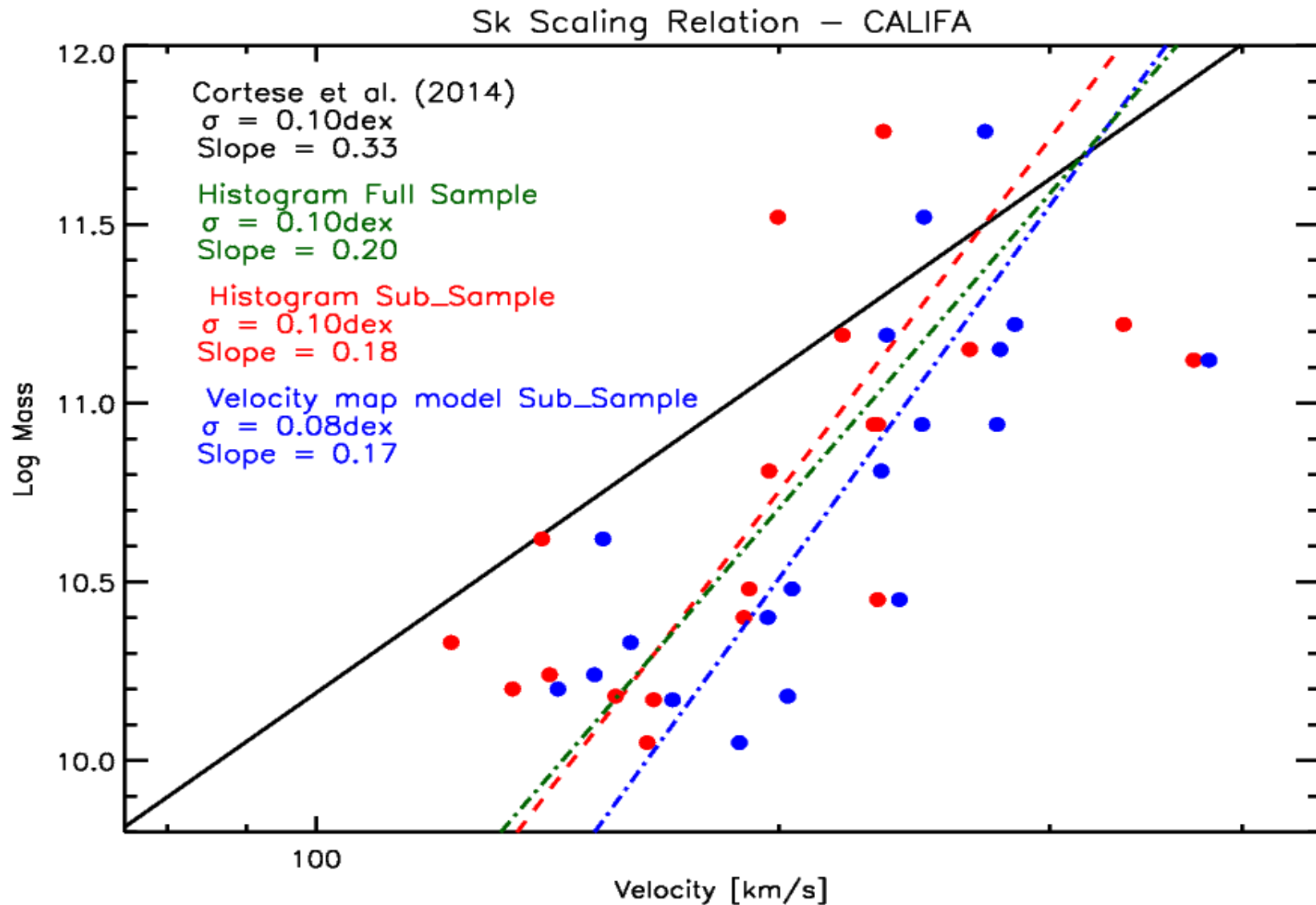
## Sk Scaling relation:

Survey	Galaxies	Slope	Intercept	Scatter
<i>SAMI</i>	<i>193</i>	0.33	-1.41	0.1dex
<i>CALIFA</i>	<i>215</i>	0.20	0.16	0.1dex
<i>MaNGA</i>	<i>357</i>	0.23	-0.20	0.1dex



work in Progress:

# A well resolved sub-sample of CALIFA galaxies



This result shows the importance of detailed kinematic analysis in Spiral galaxies.

# MCMC ANALYSIS OF BIASES IN THE INTERPRETATION OF DISK GALAXY KINEMATICS.

E. Aquino-Ortiz, O. Valenzuela, M. Cano-Díaz, S. F. Sánchez, H. Hernández-Toledo.  
Institute of Astronomy, National Autonomous University of México

## ABSTRACT

The new generation of galaxy surveys like SDSS, CUBES and MANGA open up the possibility of studying simultaneously properties of galaxies such as spiral arms, bars, disk geometry and orientation, stellar and gas mass distribution, 2D kinematics, etc. The previous task involves exploring a complicated multi-dimensional parameter space. Paglioli et al. (2009) introduce a Bayesian method and MCMC (Markov Chain Monte Carlo) techniques to model and deconvolve results of spiral galaxies. In our study we used synthetic velocity fields that include non-circular motions and assume different disk orientations in order to produce mock observations. We apply popular reconstruction techniques in order to estimate the geometrical disk parameters, system velocities, rotation curve shape and maximum circular velocity which are crucial to construct the scaling relations. We conclude that a detailed analysis of kinematics in galaxies using MCMC technique will be reflected in accurate estimations of galaxy properties and more robust scaling relations, otherwise physical conclusions may be importantly biased.

## INTRODUCTION

The most robust predictions of the cosmological model  $\Lambda$ CDM is the “dark matter crisis” (Peters et al. 2009) which can be traced and is maximum circular velocity function for halos and subhalos (Peters et al. 2011). To understand more about dark matter halos we have the scaling relations as Tully-Fisher (Tully & Fisher 1977) and Faber-Jackson (Faber & Jackson 1975) which connect dark matter halos properties with galaxy observables. For example, TFR connects the halo maximum circular velocity with the integrated luminosity, i.e., luminosity and this relation also often, some insights into the physics of disk galaxy formation and evolution.

Wright (2007) studied the TFR in four bands B, R, I and K for three different estimations of rotational velocity, he found that scatter and slope depend on the technique used to estimate the rotational velocity. We using a sub-sample of CALIFA galaxies did a comparison between the TFR with the Vrot estimated with the value of only  $\alpha$  angles and modeling the velocity field. In Figure 1 show the results, where scatter and slope decrease with Vrot estimated modeling the velocity maps in agreement with Wright (2007).

Figure 1. Comparison between the Tully-Fisher and TFR with Vrot estimated with the velocity map and Vrot estimated with the value of only  $\alpha$  angles and modeling the velocity map. Black dots represent Vrot with the largest and blue Vrot modeling kinematic map.

On any scenario, the formation, nuclear activity, inflows, outflows can produce non-circular motions in the disk and in the Vrot estimations. The Fig. 1 shows the importance of disk kinematics in relation to galaxies.

## SYNTHETIC VELOCITY MAPS

In order to study the non-circular motions, effect in the Vrot estimations in galaxies we construct a great variety of synthetic velocity maps including a bi-symmetric distribution as a bar by using the relation:

$$V_{\text{model}} = V_{\text{eq}} + \sin(\theta) [V_1 \cos(\theta) - V_2 \cos(2\theta)] \cos(\phi) - V_{1x} \sin(2\theta) \sin(\phi). \quad (1)$$

Where  $V_{\text{eq}}$  is the system velocity,  $\theta$  is the inclination,  $V_1$  is the radial velocity component,  $\phi$  is the azimuthal angle from the center as in the plane of the disk,  $\theta_0$  the angles relative to the bar axis,  $V_{1x}$  and  $V_{2x}$  are the amplitudes of the tangential and radial components of the non-circular flow, respectively.

In Figure 2 we show three synthetic velocity maps for different geometrical configurations, i.e., with different bar length and outflow angle, as well as different bar orientations.

Figure 2. Three synthetic velocity maps and contour plots for the case of a bi-symmetric bar, respectively: (a)  $L=10$ , (b)  $L=20$  and (c)  $L=30$ . (d)  $L=40$ , (e)  $L=50$  and (f)  $L=60$ . (g)  $L=70$ , (h)  $L=80$  and (i)  $L=90$ .

In the next section we modeled the synthetic velocity maps to explore if we can recover geometrical parameters, maximum circular velocity and the rotation curve shape.

## KINEMATIC ANALYSIS

To carry out our kinematic modeling of velocity maps we use the publicly available Vrot code developed by Spitzer and Sefoul (2007). This code allows in three types of kinematic models. The simplest model includes rotation only, the second model includes  $\alpha$  angles as a rotating galaxy and finally bi-symmetric model (including non-circular flows produced by a bar). Assuming a flat disk and using a Fourier series decomposition around center  $\alpha$  angles velocity rotation curve velocity, kinematic curve (v,  $\alpha$ ), inclination, disk  $\theta_0$  and rotational velocity, moreover for bi-symmetric distribution we also need determine the bar position angle  $\phi_0$  and the velocity maps as well as radial and tangential non-circular motions components.

Vrot use a Bayesian-informed (MCMC) algorithm as a minimization technique. The MCMC algorithm uses a maximum likelihood approach to assess the goodness. How likely is the data set given a set of geometric parameters. This routine minimizes the  $\chi^2$  between the observed and the model by using a gradient search through parameter space. The errors with best-fitted approaches is that for data with less than 1000 sampling, corresponding to very local rotation in  $\alpha$ -space. The MCMC is sensitive to initial guesses and is easily trapped.

To solve this problem we implement a Bayesian technique and a *Markov Chain Monte Carlo* (MCMC) the provides a method of varying the parameter space that is fully convergent to the posterior probability distribution of the input parameters using the Metropolis-Hastings algorithm, e.g. Paglioli et al. (2009).

## RESULTS

The synthetic dataset tell us that if we consider a large number of iterations we ensure that we are covering the entire space of parameters. The following figures show the results of the detailed kinematic analysis for three synthetic velocity maps with different geometry.

Figure 3. Velocity map with  $L=10$ ,  $\theta_0=20^\circ$  including a bi-symmetric distribution and a bar with  $\phi_0=0^\circ$ . In this case the rotation curve including only rotational velocity (red curve) converges to the rotation curve used to construct the synthetic map (black curve). When we modeled including a bi-symmetric distribution we can recover the rotation curve (blue curve) in agreement with the synthetic.

Figure 4. Velocity map with  $L=20$ ,  $\theta_0=20^\circ$  including a bi-symmetric distribution and a bar with  $\phi_0=0^\circ$ . In this case the rotation curve including only rotational velocity (red curve) converges to the rotation curve used to construct the synthetic map (black curve). When we modeled including a bi-symmetric distribution we can recover the rotation curve (blue curve) in agreement with the synthetic.

Figure 5. Velocity map with  $L=30$ ,  $\theta_0=20^\circ$  including a bi-symmetric distribution and a bar with  $\phi_0=0^\circ$ . In this case the rotation curve including only rotational velocity (red curve) converges to the rotation curve used to construct the synthetic map (black curve). When we modeled including a bi-symmetric distribution we can recover the rotation curve (blue curve) in agreement with the synthetic.

## DISCUSSION AND CONCLUSIONS

In this paper we show three important examples in order to show that for the model including only rotation velocity the rotation curve shape is affected due to the region where we have non-circular motions (See Fig. 3, 4 and 5) can be used as a non-circular flow in several cases (including bars in mass distribution and maximum velocity in the disk). When modeling only rotation velocity, we modeled with our MCMC, we include of rotation curve velocity, the bi-symmetric model the non-circular curve and the non-circular motions and we can see that we recover the rotation curve shape, the geometrical parameters and the maximum circular velocity.

We conclude that a detailed analysis of kinematic in galaxies using MCMC technique will be reflected in accurate estimations of galaxy properties, and more robust scaling relations, otherwise physical conclusions may be importantly biased.

# CONCLUSIONS:

- Scaling relation using the  $S$  parameter is more tight than Tully-Fisher and Faber-Jackson relation.
- There is a possible indication of systematic differences between scaling relations using different samples (SAMI, CALIFA and MaNGA).
- We emphasize the importance of detail study of kinematics in galaxies.
- After understanding all possible uncertainties we will be ready to test theoretical models.